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MSAR 71-74

FINAL REPORT

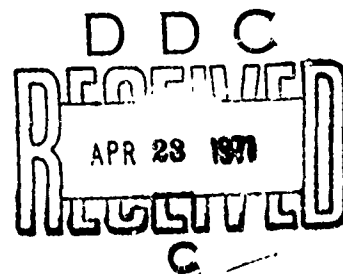
THE DESIGN AND FABRICATION OF ONE (1)
PROTOTYPE PORTABLE SMOKE AND
GAS REMOVAL UNIT (U)

March, 1971

Report No. CR 71.007
Contract No. N62399-69-C-0038 *NEW*

to

Naval Civil Engineering Laboratory
Port Hueneme, California 93043



An investigation conducted by:
MSA RESEARCH CORPORATION
Division of Mine Safety Appliances Company
Evans City, Pennsylvania 16033

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Each of the following agencies
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TABLE OF CONTENTS

	<u>Page</u>
1.0 INTRODUCTION	1
2.0 DESIGN OF PROTOTYPE UNIT	2
2.1 Lithium Hydroxide Efficiency Tests	2
2.2 System Design	2
2.2.1 Lithium Hydroxide Bed	3
2.2.2 Activated Charcoal Bed	3
2.2.3 Drying Agent	3
2.2.4 Carbon Monoxide Oxidizing Agent	4
2.2.5 Prefilter	4
2.2.6 Particulate Filter	4
2.2.7 Housing	4
2.2.8 Filter and Chemical Bed Construction	4
2.2.9 Blower	4
2.2.10 Motor and Controls	5
2.2.11 Platform Truck	5
2.2.12 Assembly	5
3.0 TEST PROCEDURE	6
4.0 DISCUSSION OF RESULTS	7
5.0 SUMMARY OF TEST RESULTS	8
APPENDIX A: Calculations - Chemical Beds	11
APPENDIX B: Mass Balance Calculations for Test No. 2	12

LIST OF TABLES

- I. Bed Replenishment List
- II. Test Apparatus
- III. Test Data, Test No. 2
- IV. Filter and Bed Element Changes

LIST OF FIGURES

- 1. Lithium Hydroxide Efficiency Test No. 1
- 2. Lithium Hydroxide Efficiency Test No. 2
- 3. Portable Smoke and Gas Removal Unit
- 4. Assembly Drawing, Portable Smoke and Gas Removal Unit
- 5. Temporary Environmental Test Facility
- 6. Access Port Structure
- 7. Interior of Temporary Environmental Test Facility
- 8. Data Curves, Test No. 2

SUMMARY

A prototype portable smoke and gas removal unit was developed to clear the atmosphere of a sealed room after a fire.

The unit utilizes a series of filters and chemical beds to remove particulate matter, carbon dioxide and carbon monoxide within three hours to such a level that a man may work safely and comfortably.

The unit is self-contained, with its own electric motor, blower, filters and chemical beds, all mounted on a portable platform truck with floor lock.

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THE DESIGN AND FABRICATION OF ONE(1) PROTOTYPE PORTABLE SMOKE AND GAS REMOVAL UNIT (U)

1.0 INTRODUCTION

The portable smoke and gas removal system is required for the purpose of removing particulate matter, carbon dioxide, carbon monoxide and other toxic gases from the atmosphere of a sealed room. The sealed room is to be 7,500 cu ft, filled with smoke and gases from Class A or Class C fires. It is required that the unit reduce the air contaminants to such a level as to permit habitation within a few hours, assuming the oxygen content of the air is at a normal level. The temperature of the air in the room is assumed to range from 50°F to 90°F while the unit is in operation.

It is required that the unit be self-contained with an integral motor, blower, and filters. The unit must be easily portable and must pass readily through standard 33 in. and 36 in. wide doorways.

A preliminary study indicated that the unit should contain a prefilter, a particulate filter, a charcoal filter to remove toxic gases, a drying agent to remove water vapor, a carbon monoxide oxidizer and a carbon dioxide absorbing agent.

The unit must be capable of performing with carbon dioxide concentrations as high as 10%, caused by the fire and possible use of carbon dioxide extinguishers.

2.0 DESIGN OF THE PROTOTYPE UNIT

Since there was no published information as to the efficiency of lithium hydroxide (LiOH) in absorbing carbon dioxide (CO₂) when the CO₂ concentration approached the 10% level, it was felt necessary to conduct laboratory tests to establish the weight of LiOH required to absorb 1 lb of CO₂ at a CO₂ concentration of about 10%.

2.1 Lithium Hydroxide Efficiency Test

Two tests were conducted at 10% CO₂ concentration at the beginning of each test to determine the efficiency of LiOH as an absorption agent for CO₂. In each test, a canister, 8-3/8 inch ID x 12 inch long was filled with 9 lb of LiOH and placed inside a room of about 600 cu ft capacity. Air from the room was moved through the canister at the rate of 20 cu ft per minute (CFM). The values of temperature of the gases from the canister and the concentration of CO₂ in the room and at the outlet of the canister were measured every few minutes. These values for the two tests are shown as a function of time in Figures 1 and 2.

To establish initial concentration of CO₂ in the room, the room was charged with a predetermined volume of CO₂ by releasing balloons filled with CO₂ inside the room, and the CO₂ concentration measured by an Orsat apparatus. An MSA model 300 Lira instrument was used to measure the CO₂ concentration exiting from the canister. As may be noted from Figure 2, a peak canister outlet temperature of about 270°F occurred at approximately 10 minutes after the start of test.

At the end of tests, the spent LiOH was titrated with acid to determine the volume of CO₂ absorbed by LiOH bed. For the two tests, the volume of CO₂ absorbed was found to be 49 and 49.6 cu ft, respectively. It was then assumed that the small residual CO₂ in the room would have been absorbed by LiOH were the test continued further than the 3 hour duration of the tests reported here. Making a small adjustment for this residual gas, it was estimated that 9 lb of LiOH in the canister was capable of absorbing 6 lb of CO₂. This ratio was used in determining the quantity of LiOH to be used in the Smoke and Gas Removal Unit.

2.2 System Design

The Smoke and Gas Removal Unit was to be designed to absorb smoke and gases generated in a 7500 cu ft room during a Class A or Class C fire and to reduce the concentrations of

the various gases to levels safe for normal habitation without regard to oxygen concentrations. Other design requirements are given in contract specification, N62399-69-C-0038.

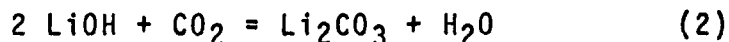
2.2.1 Lithium Hydroxide Bed. It was assumed that a room of 7500 cu ft capacity will have approximately 14 lb of carbon monoxide (CO) after a class A or class C fire. Hopcalite, a proprietary catalytic agent of coprecipitated manganese and copper oxides, was decided upon to oxidize this CO into CO₂ which was then to be absorbed by the LiOH bed. Based upon the reaction shown in Equation (1), it was determined that 14 lb of CO will produce 22 lb of CO₂.



In addition, a 10% concentration of CO₂ in the room at the end of fire was calculated to be equivalent to approximately 65 lb of CO₂. Therefore, a total of 87 lb (65 + 22) of CO₂ was to be absorbed by the LiOH bed. At the absorption rate of 0.67 lb of CO₂ per lb of LiOH, a total of 130.5 lb of LiOH was considered necessary for the purposed prototype unit.

2.2.2 Activated Charcoal Bed. The contract specification required a minimum of twenty lb of activated charcoal to remove 4 lb of toxic gases. The system was designed to provide 25 lb of activated charcoal, 6-10 mesh, MSA Part No. 21104. This quantity was based on a 0.25 second contact time for the gas flowing through the bed. The calculations are shown in Appendix A.

2.2.3 Drying Bed. A drying bed was considered necessary for the removal of water from the air to prevent poisoning the hopcalite, the CO oxidizing agent. It was decided to use silica gel to remove most of the water generated during the carbon dioxide-lithium hydroxide reaction. From the chemical reaction shown in Equation (2), it was estimated that a total of 35.6 lb of water will be generated in the LiOH trays.



Approximately 140 lb of silica gel is required to absorb 35.6 lb of water. However, due to limitations in the weight, size, and pressure drop through the unit, it was considered impractical to aim for complete removal of water generated during CO₂ absorption. It was, therefore, decided to limit the quantity of silica gel to 45 lb.

2.2.4 Carbon Monoxide Oxidizing Agent. The material for oxidizing carbon monoxide was hopcalite. A total of 55 lb moisture tolerant hopcalite was used (MSA Part No. 21215). This quantity was based on a 1/4 second contact time. Calculations to determine the required amount are shown in Appendix A. Moisture tolerant hopcalite has a higher capacity to convert CO to CO₂ than do the standard hopcalite materials. It will pass less than 0.01% CO out with 0.1% CO in with moisture level of 45 mg H₂O per gram hopcalite. The temperature limit on the hopcalite is 800°F.

2.2.5 Prefilter. The MSA AIR-O-KAY prefilter No. 15-38191, with modifications, was selected as the prefilter. The AIR-O-KAY prefilter is useful to extend the life of the more costly DUSTFOE elements by stopping and holding a high percentage of the larger particulate matter. Initial pressure drop at 1000 SCFM is less than 0.1 in. W.G.

2.2.6 Particulate Filter. The MSA DUSTFOE filter No. 15-87407, with modifications, was selected as the particulate filter. This filter, which corresponds to the MSA B-1000, provides 55% maximum penetration and 0.25 in. W.G. maximum initial pressure drop when penetration tested with 0.3 micron diameter DOP smoke particles in accordance with MIL-STD-282.

2.2.7 Housing. As shown in Figure 3, the system was designed with a stainless steel housing with a removable cover. The housing is 28 in. ID x 48 in. high and is equipped with two support flanges, one for the two-filter assembly and one for the chemical bed.

2.2.8 Filter and Chemical Bed Construction. Figure 3 shows the beds arranged in their stacked sequence. Air flow is vertically upward through the filters and chemical beds, with the inlet in a plenum chamber below No. 1, Prefilter. The two filters are riveted together into one assembly.

Each filter and bed is constructed of a rolled stainless steel flange with a grid support of heavy duty stainless steel wire cloth. Fine mesh screens and fiberglass cloths are used in each chemical bed to retain the bed particles.

2.2.9 Blower. The blower selected is a high-pressure direct-driven centrifugal blower, Dayton Electric Manufacturing Company, No. 4C108. When driven with a 1 HP motor, delivery rates are as follows:

Static Pressure, in. H ₂ O	1	2	3	4	5	6
CFM at 3450 RPM	810	748	682	610	510	370
CFM at 2700 RPM	634	585	534	477	398	289

2.2.10 Motor and Controls. The motor selected is a 1 HP permanent magnet motor, 3600 RPM, Applied Motors Inc., No. VC3632-497-56B. The motor is equipped with vibration isolator mounts and a special housing and stand fabricated by MSAR.

An SCR power supply, speed control and switch is panel mounted in the housing. A 75 ft power cord of 3-conductor No. 12 wire and a cord holder are provided with the unit.

2.2.11 Platform Truck. A 30 in. wide x 60 in. long aluminum platform truck is provided to support the system. The truck is equipped with a foot-operated floor lock and a handle bar.

2.2.12 Assembly. In Figure 4 is an assembly drawing of the system, ref. MSAR drawing A-SK-1818-2.

3.0 TEST PROCEDURE

Test No. 1

Upon completion of fabrication the portable smoke and gas removal unit was loaded and assembled in preparation for testing. The chemical beds and filters were loaded with chemicals in the order and amounts shown in Table I. The test apparatus listed in Table II was assembled and prepared for testing.

The SAR fire testing facility was selected for the test building. Since it is a 10,000 cu ft building, the excess volume of 2,500 cu ft was reduced to the required 7,500 cu ft by inflating a 2,500 cu ft vinyl bag of air inside the facility. Obvious leaks in the building were sealed by taping.

Before the test, a considerable amount of smoke was generated in the test building by burning a rubber tire and styrofoam material, and CO and CO₂ gases were added from plastic bags. The circulating fan was used to mix the gases in the room and the test was started.

After only 20 minutes, the test was stopped because of the observed leakage of gases from the building. It was evident that the building was not sealed properly for the test because of the excessive leakage of smoke from the corrugated metal seams and joints. The rate at which the CO and CO₂ concentrations in the room dropped during this time was also judged to be abnormally high compared to the lithium hydroxide efficiency tests run previously. Therefore, the test was discontinued.

Corrective action on the test building was considered but sealing of the building was found to be impractical because the sealing materials were not compatible with other fire testing work. The usage of other available MSAR buildings, and also other industrial buildings in the area, was evaluated and ruled out for economic, insurance or liability considerations. At this point it was decided to prepare plans for a temporary environmental test facility employing two inflatable vinyl bags, each having a capacity of 3,750 cu ft. Vinyl bags were chosen as the environmental test facility since these and Mylar bags are used for gas sampling. Although we have no permeability data on diffusion of CO and CO₂ through the vinyl bags, we believed it minimal since the test was conducted within a half hour after releasing the CO and CO₂ into the environmental test facility. This test is described below.

Test No. 2

A test facility composed of two(2) 3,750 cu ft vinyl bags with a sealed access port was designed, fabricated and assembled. The bags were individually attached and sealed to the access port frame. The facility is illustrated in the following figures:

Figure 5 - Temporary Environmental Test Facility

Figure 6 - Access Port Structure

Figure 7 - Interior of Temporary Environmental Test Facility

Figure 5 shows the exterior of the temporary environmental test facility. The necessary testing volume is formed by two(2) 3,750 cu ft vinyl bags, each approximately 15 ft dia. x 20 ft long. Bags of this type, in smaller sizes, had been successfully used at MSAR for similar applications.

Figure 6 shows the access port structure which performs the following functions:

- Provides a sealed access door for passage of personnel and the portable smoke and gas removal unit.
- Provides a support platform for the portable smoke and gas removal unit.
- Joins and anchors the vinyl bags in the middle of the facility.

A view of the interior of one of the bags, after inflation, is shown in Figure 7.

A 900 CFM circulating blower was set up inside the facility to insure mixing of the atmosphere especially the CO and CO₂ gases when released into the facility.

Once the facility and measuring equipment were connected, a container of styrofoam was burned to produce smoke in the building. Predetermined amounts of the CO and CO₂ were then released inside the facility by opening previously filled vinyl bags. The quantities measured and the equipment used were the same as described in Test No. 1, and detailed in Table II. The data recorded during the test are given in Table III and plotted in Figure 8.

4.0 DISCUSSION OF RESULTS

Test No. 2. After 110 minutes, the CO₂ LIRA instrument began to behave erratically, as noted by increase in the facility CO₂ level. This may have been caused by condensation of water vapor within the instrument. The LIRA instrument was immediately checked by measuring the CO₂ with 3% CO₂-in-air calibrating gas. The LIRA gave a 4% CO₂ level, indicating that the LIRA was reading high. Another check was made with the LIRA in which air was sampled. The LIRA gave a reading of 0.5%. Since air is essentially 0% CO₂, the LIRA was reading high by 0.5 to 1.0%.

A chemical assay of spent chemicals and a study of the filter elements was made after the test. The results are itemized in Table IV. A 1 lb sample of LiOH was removed from each bed and acid titrated to measure absorbed CO₂.

A total of 631 ft³ CO₂ was calculated from this analysis; the initial or inlet bed absorbed 252 ft³, the middle bed 224 ft³ and the outlet bed 155 ft³. A mass balance calculation was made and this is given in Appendix B. From a mass balance approach, a 1% CO₂ concentration was present in the test facility.

The adsorption of water by the silica gel was determined by weight. The 45 lb charge of silica gel weighed 55-3/4 lb, or a net gain of approximately 24%.

The theoretical (maximum) removal rates of CO₂ and CO for the test are plotted on Figure 8. The figure shows that time to reach 1% CO₂ requires 110 minutes at the 200 CFM flow rate. The actual performance lagged behind the calculated maximum removal rate. This is also shown to be the case with CO; the actual performance rate lags the calculated rate.

The absorption rates were computed from a rate equation assuming that CO₂ concentration is 0% leaving the LiOH beds (100% removal efficiency). The bed configuration of the unit has the hopcalite bed on the outlet end. Therefore, CO₂ converted from CO was expelled back into the test facility. As a result the rate equations representing this configuration for CO₂ and CO concentrations in the chamber are respectively

$$X = X_0 e^{-\frac{Qt}{V}} + \frac{Q}{V} Y_0 t e^{-\frac{Qt}{V}} \quad (3)$$

(CO₂ conc = removal + generation) for CO₂

and $Y = Y_0 e^{-\frac{Qt}{V}}$ for CO

(CO conc = removal + no generation)

where X = Instantaneous volume of CO₂ in the test facility, ft³.
 X₀ = initial CO₂ volume, 525 ft³
 Y₀ = Instantaneous volume of CO in the test facility, ft³.
 Y = initial CO volume, 195 ft³
 V₀ = chamber volume, ft³ (7500 ft³)
 Q = flow rate, cfm (200 cfm)
 t = time, minutes

These equations were put into a computer and the computer readouts for CO₂ and CO concentrations are plotted in Figure 8, as mentioned previously.

With a bed arrangement in which a LiOH bed follows the hopcalite bed, CO₂ theoretically would not be expelled into the test facility. The second term in Equation (3) will therefore be equal to zero, giving

$$X = X_0 e^{-\frac{Qt}{V}} \quad (4)$$

Theoretically, therefore, the removal of CO₂ would be more rapid whereas the concentration of CO would be unaffected. In this latter case, 1% CO₂ concentration would be achieved in 75 minutes.

With the configuration tested, with 100% removal of CO₂ through the LiOH and 1.0% CO₂ in two hours in the test facility, the flow rates required for various initial CO₂ concentrations are as follows:

<u>Initial CO₂ Conc (%)</u>	<u>Flow Rates (CFM)</u>
8	358
7	327
5	201

5.0 SUMMARY OF TEST RESULTS

In summary, the test program has demonstrated the following:

1. The unit effectively removes CO
2. The unit removes CO₂
3. The unit removes some water, but not all the water produced
4. Further testing is required to demonstrate the performance of the unit.

APPENDIX A

CALCULATIONS: CHEMICAL BEDS

The system design is based on bed diameters of 27 inches. It was assumed that a 1/4 second contact time in the charcoal and Hopcalite beds should be adequate.

Activated Charcoal Beds

For a flowrate (Q) through the charcoal bed of cross-sectional area (A), the thickness (S) of the bed to insure a contact time (t) is given by:

$$S = \frac{Qt}{A}$$

For a flowrate of 200 CFM through a cross-sectional area of 4.0 sq ft and a contact time of 1/4 second (1/240 minute), the bed thickness is given by:

$$S = \frac{200 \times 1}{240 \times 4} = \underline{0.21 \text{ ft}}$$

The total weight of activated charcoal needed in the unit is, therefore,

$$\begin{aligned} W &= \text{density of charcoal} \times \text{volume of the bed} \\ &= 30 \times 4.0 \times 0.21 \\ &= \underline{25.2 \text{ lbs}} \end{aligned}$$

Hopcalite Bed

Since it is planned to use the same size beds for both charcoal and Hopcalite, the weight of Hopcalite required is given by:

$$\begin{aligned} W &= \text{density of Hopcalite} \times \text{volume of the bed} \\ &= 65 \times 4.0 \times 0.21 \\ &= 54.5 \text{ lbs, say } \underline{55 \text{ lbs}} \end{aligned}$$

APPENDIX B

MASS BALANCE CALCULATIONS FOR TEST NO. 2

Chemical Assay of Beds, LiOH

Inlet Bed	252 ft ³ CO ₂
Middle Bed	224 ft ³ CO ₂
Outlet Bed	154.7 ft ³ CO ₂
Total	630.7 ft ³ CO ₂

Mass Balance on System

Initial CO ₂ Conc.	7%
Initial CO Conc.	2.6%

Initial Quantity CO₂ in the test facility

$$7500 \text{ ft}^3 \times 0.07 = 525.0 \text{ ft}^3 \text{ CO}_2$$

Initial Quantity CO in the test facility

$$7500 \text{ ft}^3 \times 0.026 = 195 \text{ ft}^3 \text{ CO}$$

CO Balance

Volume of CO at the beginning of the test = 195 ft³

Concentration of CO at the end of the test = 0.2%

Volume of CO at the end of test = $7500 \times 0.002 = 15 \text{ ft}^3$

CO converted to CO₂ during the test = $195 - 15 = 180 \text{ ft}^3$

Total volume of CO₂ available for absorption = Initial
CO₂ in the test facility
plus CO₂ converted from CO
= $525 + 180 = 705 \text{ ft}^3$

TABLE I
BED REPLENISHMENT LIST

PORTABLE SMOKE AND GAS REMOVAL UNIT
PROTOTYPE UNIT

<u>Bed No.</u>	<u>Amount Required</u>	<u>Description</u>
1	1	Prefilter Assembly, MSAR SK 1-227-1
2	1	Filter Assembly, MSAR SK 1-231-1
3	25 lb	Activated charcoal, 6-10 mesh MSA part No. 21104
4	45 lb	Silica Gel, 8-14 mesh MSA part No. 21177
5 } 6 } 7 }	45 lb in each bed	Lithium hydroxide, 4-8 mesh MSA part No. 20457
8	55 lb	Hopcalite, 8-12 mesh. MSA part No. 21215

TABLE II
TEST APPARATUS

<u>Item</u>	<u>Characteristic</u>	<u>Apparatus Used</u>	<u>Location</u>
1	CO ₂ Concentration	MSA Model 300 LIRA Analyzer, with sample pump.	IN - Environmental chamber OUT- Discharge gas stream of unit
2	CO Concentration	MSA Explosimeter with special calibration, with sample pump.	IN - Environmental chamber OUT- Discharge gas stream of unit
3	O ₂ Concentration	Beckman Model C2 Oxygen Analyzer	IN - Environmental chamber
4	Pressure Drop	Water Draft Guage	IN - Unit prefilter plenum OUT- Environmental chamber
5	Temperature	API Temperature Indicator, Iron-constantan Thermocouples	IN - Environmental chamber OUT- Discharge gas stream of unit SHELL-On O.D. of unit MOTOR-On unit blower motor case
6	Gas Flow	Taylor No. J012 Aenometer	Discharge gas stream of unit
7	CO ₂ Concentration	MSA Detector Tube, Part No. 85976	Use manual sample pump to withdraw gas sample from the desired location. Color staining indicates concentration
8	CO Concentration	MSA Detector Tube, Part No. 91229	

TABLE III

TEST DATA, TEST NO. 2
Portable Smoke and Gas Removal Unit

Date: 29 July 1970

Date: 29 July 1971

Time, min.	CO ₂ Conc.		CO Conc.		O ₂ %	ΔP In H ₂ O	Temp. °F			
	IN	OUT	IN	OUT			IN	OUT	SHELL	MOTOR
1730	Started fire, burning container of styrofoam to fill space with smoke.									
	Started releasing CO ₂ and CO gases into bags.									
	Amount released:									
	CO - 230 SCF, (3.42% Concentration)									
	CO ₂ - 540 SCF, (7.98% Concentration)									
	Started circulating blowers.					Started test.				
1815	5.5	---	2.4	---	18	6.25	80	110	80	90
1820	7.0	---	1.8	---	18	6.25	70	150	80	90
1825	6.4	---	---	---	18	6.25	75	150	80	90
1830	6.3	---	2.5	---	18	6.25	70	170	70	85
1835	---	3.6	---	0	18	6.25	70	180	70	85
1840	---	3.2	---	0	18	6.25	70	320	70	85
1845	6.1	---	---	0	18	6.25	75	530	60	90
1850	---	4.0	2.25	---	18	6.25	85	580	60	100
1855	---	3.8	---	0	18	6.25	80	560	60	100
1900	5.6	---	1.62	---	18	6.25	80	540	65	100
1905	5.6	---	1.4	---	18	6.25	80	490	70	100
1910	---	---	---	---	18	6.25	80	485	70	105
1915	---	3.2	---	0	18	6.25	80	530	80	110
1920	4.8	---	1.2	---	18	6.25	80	510	80	110
1925	4.7	---	1.0	---	18	6.25	80	510	80	110
1930	---	3.7	---	0.62	18	6.25	80	450	80	110
1935	---	4.0	---	0.5	18	6.25	80	460	85	115
1940	4.4	---	0.87	---	18	6.25	80	540	85	115
1945	---	3.7	---	0.87	18	6.25	85	510	85	115
1950	4.0	---	0.87	---	18	6.25	85	560	80	115
1955	---	3.2	---	0.45	18	6.25	80	560	80	110
2000	3.7	---	0.54	---	18	6.25	80	525	80	110
2005	---	2.9	---	0.35	18	6.25	80	485	80	110
2010	3.4	---	0.4	---	18	6.25	75	390	80	110
2015	---	2.6	---	0.25	18	6.25	75	405	80	110
2020	3.8	---	0.32	---	18	6.25	80	400	80	110
2025	---	3.5	---	0.25	18	6.25	75	300	80	110
2030	---	---	---	---	18	6.25	--	330	--	---
2035	---	3.2	---	---	18	6.25	75	350	75	105

TABLE III (continued)

Date: 29 July 1970

Time, min.	CO ₂ Conc.		CO Conc.		O ₂ %	ΔP In. H ₂ O	Temp. °F			
	IN	OUT	IN	OUT			IN	OUT	SHELL	MOTOR
2050	---	2.8	---	0	18	6.25		350		
2055	3.0	---	0.2	---						
<p>Checked calibration of CO₂ LIRA instrument with 3% CO₂ calibration gas. Result: 4.1 reading. Therefore, CO₂ LIRA readings taken during the latter stages of the test are questionable although the instrument had been calibrated and checked prior to the test. This difficulty could possibly have been caused by the condensation of water vapor in the sample lines during the latter stages</p>										
2055	Room	CO ₂ :	1.2% Conc. measured with a CO ₂ detector tube.							
	Room	CO:	120 ppm, measured with a CO detector tube.							

TABLE IV

FILTER AND BED ELEMENT CHANGES
Portable Smoke and Gas Removal Unit

Test 2

No.	Element	Weight, lb		Remarks
		Before Test	After Test	
1	Prefilter, MSA Air-O-Kay	--	--	Collected numerous black particles
2	Particulate Filter, MSA Dustfoe	--	--	Collected some black particles, including some activated charcoal from bed above
3	Activated charcoal, 6-10 mesh, MSA part No. 21104	25	29	+ 4
4	Silica gel, 8-14 mesh, MSA part No. 21177	45	55-3/4	+10-3/4
5	Lithium hydroxide, 4-8 mesh, MSA part No. 20457	45	64	+19
6	Lithium hydroxide, 4-8 mesh, MSA part No. 20457	45	61-3/4	+16-3/4
7	Lithium hydroxide, 4-8 mesh, MSA part No. 20457	45	54-3/4	+ 9-3/4
8	Hopcalite, 8-12 mesh, MSA part No. 21215	55	54-3/8	- 5/8

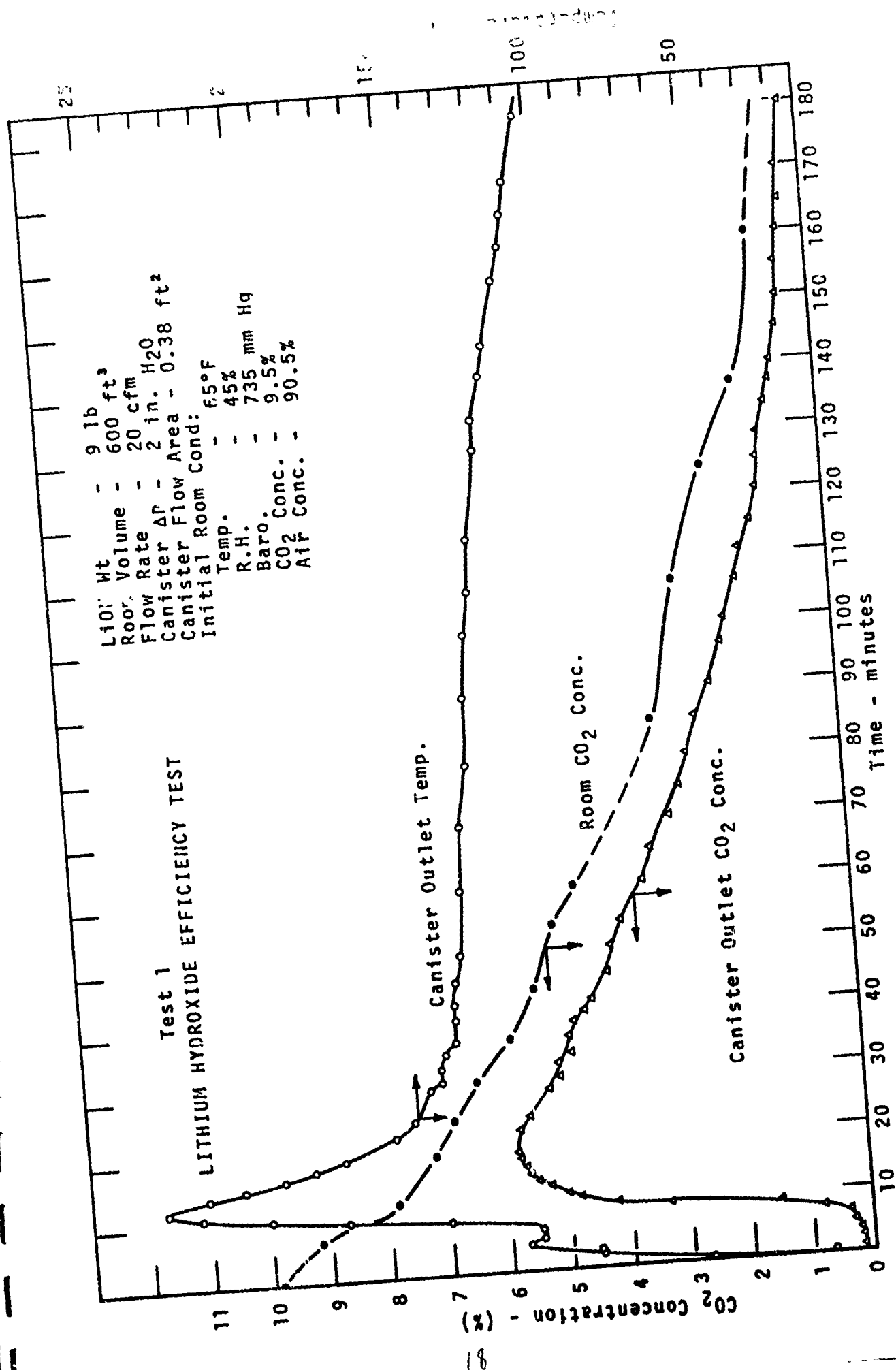


FIGURE 1

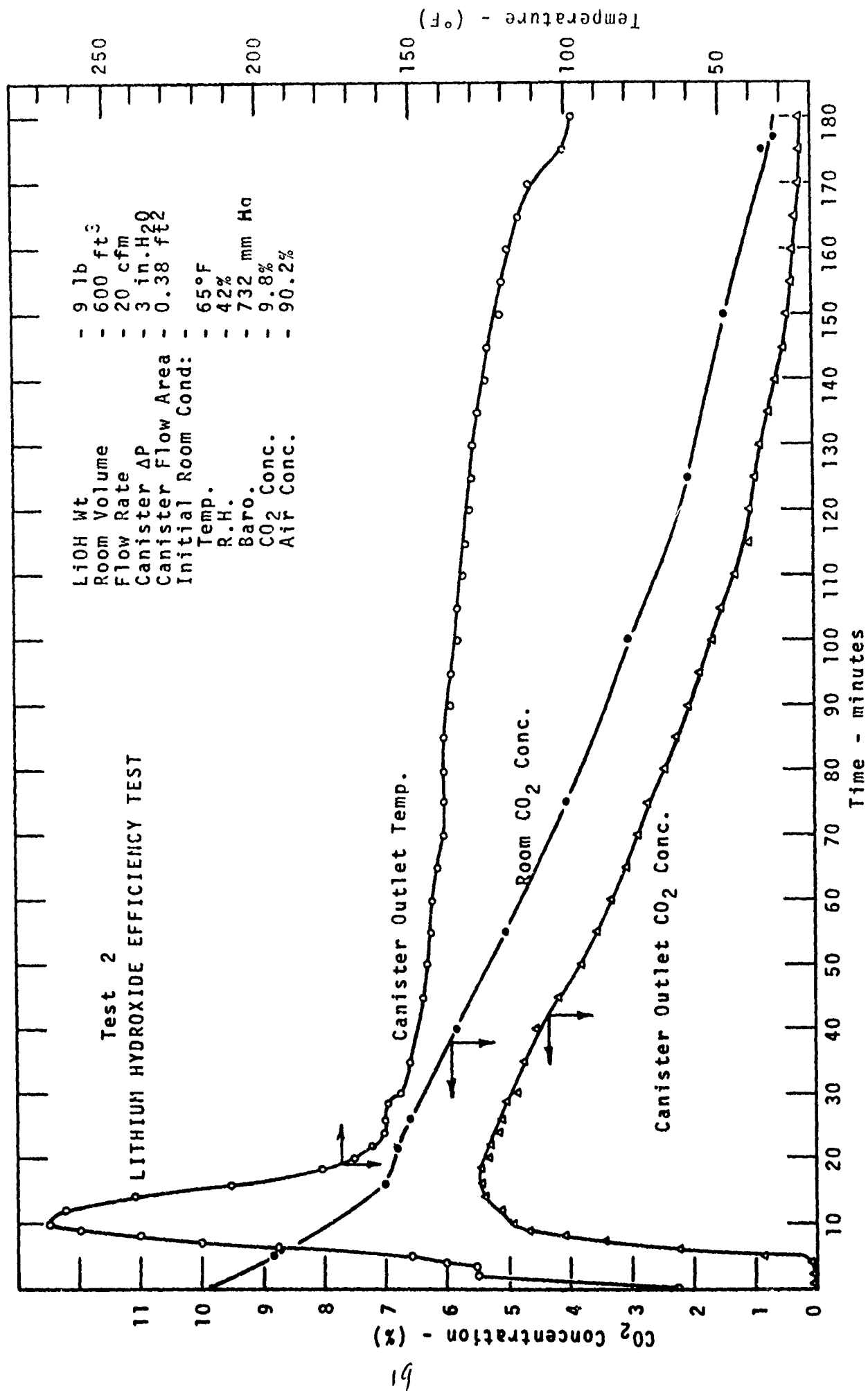


FIGURE 2

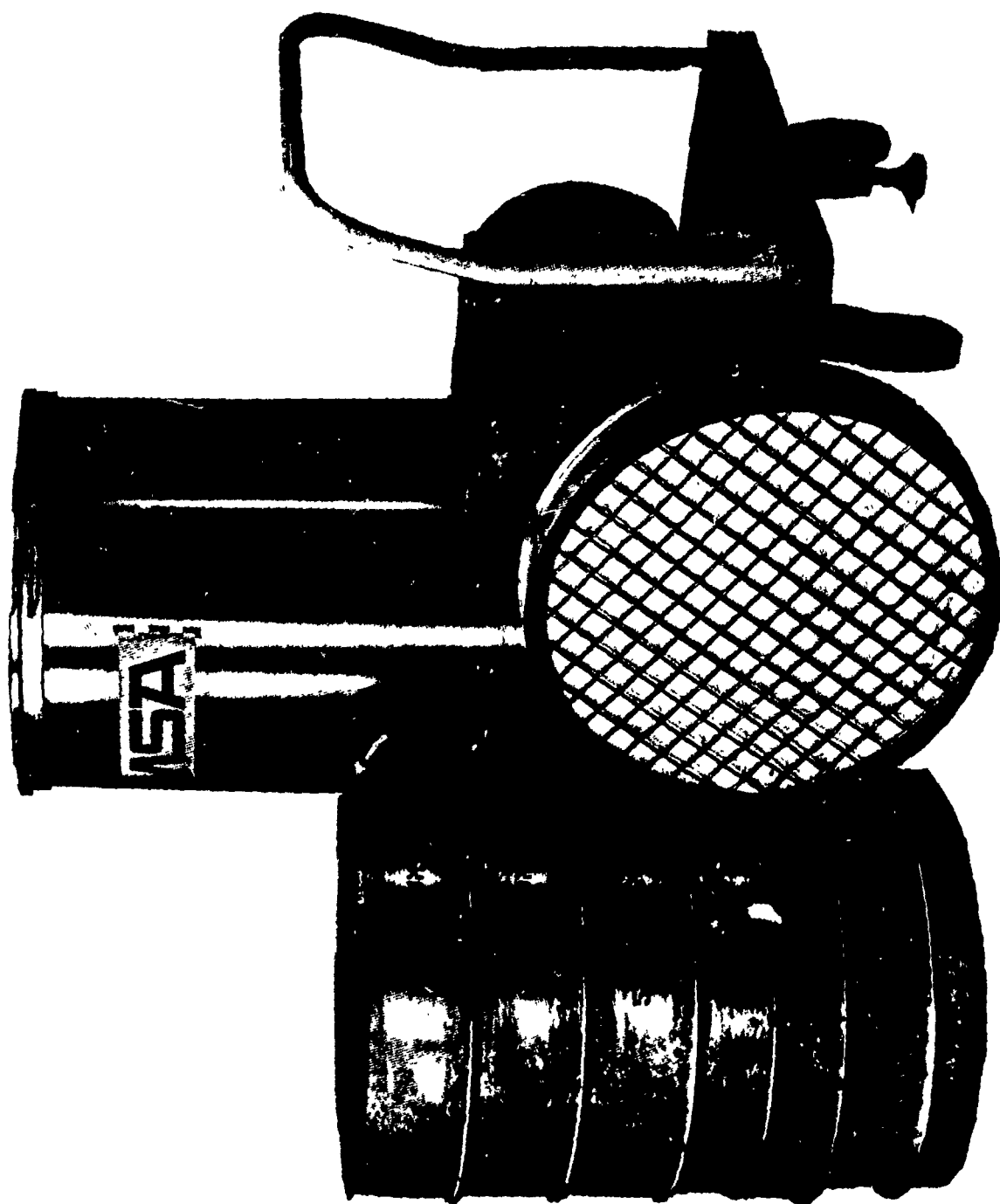


FIGURE 3. PORTABLE SMOKE AND GAS REMOVAL UNIT

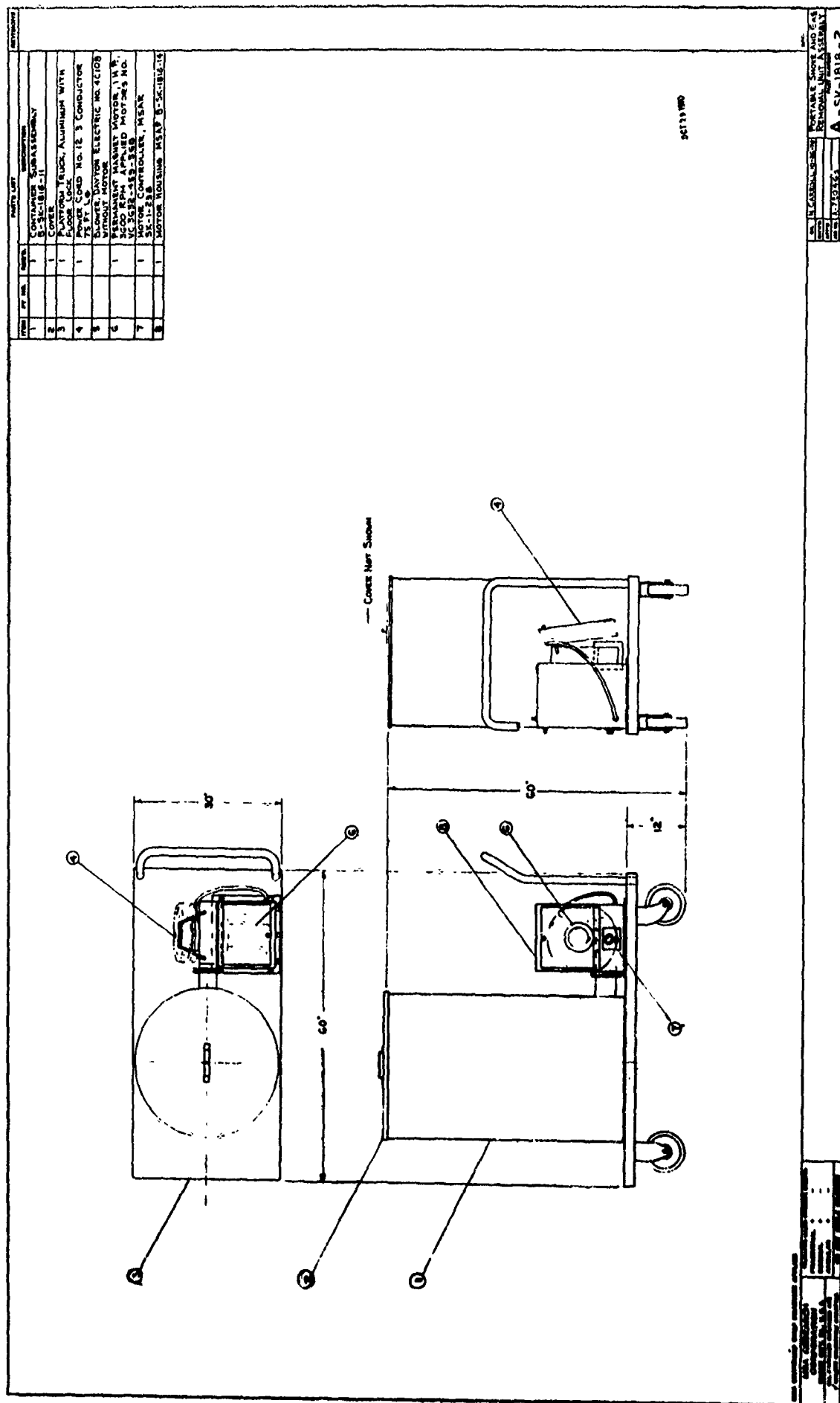


FIGURE 4.
ASSEMBLY DRAWING, PORTABLE SMOKE AND GAS REMOVAL UNIT

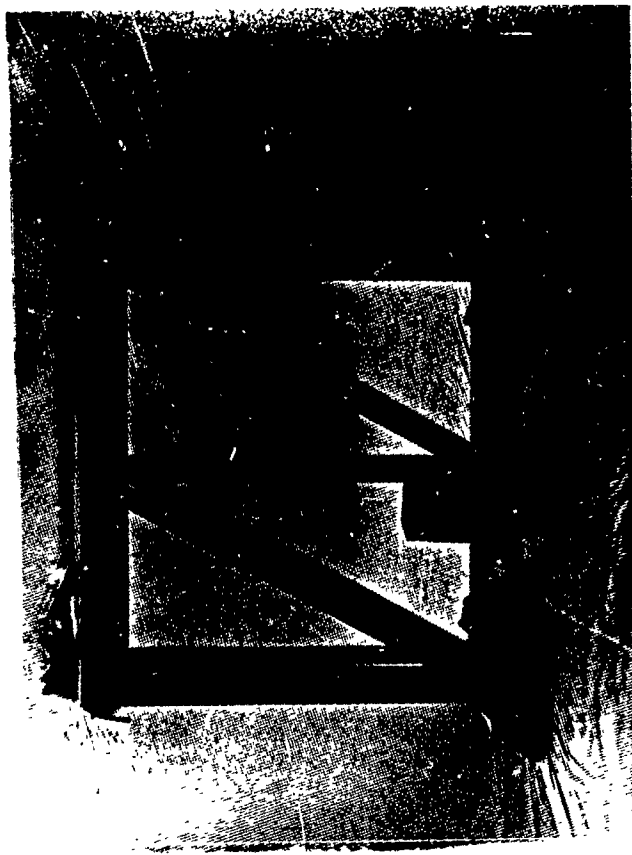
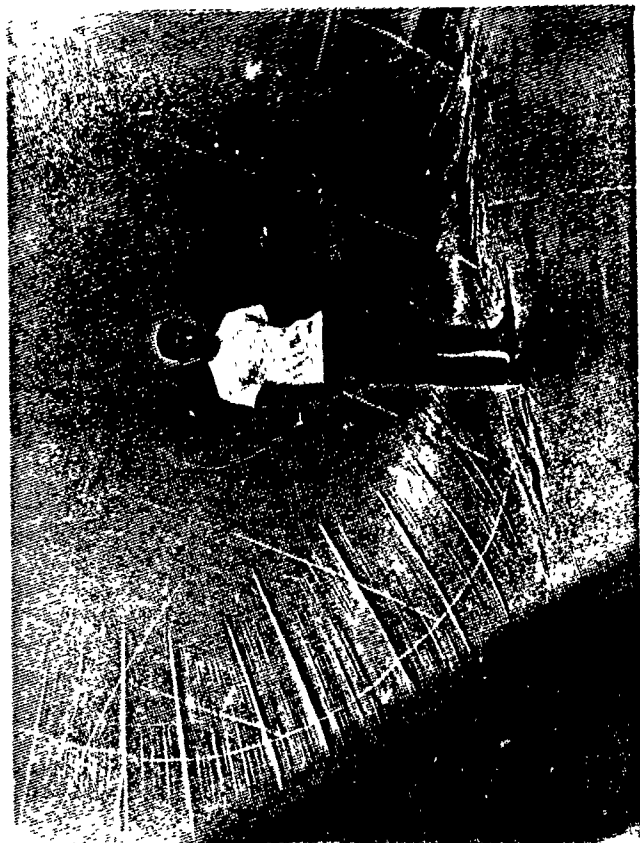


FIGURE 6. ACCESS PORT STRUCTURE



NOT REPRODUCIBLE



FIGURE 5. TEMPORARY ENVIRONMENTAL TEST FACILITY

FIGURE 7. INTERIOR OF TEMPORARY ENVIRONMENTAL TEST FACILITY

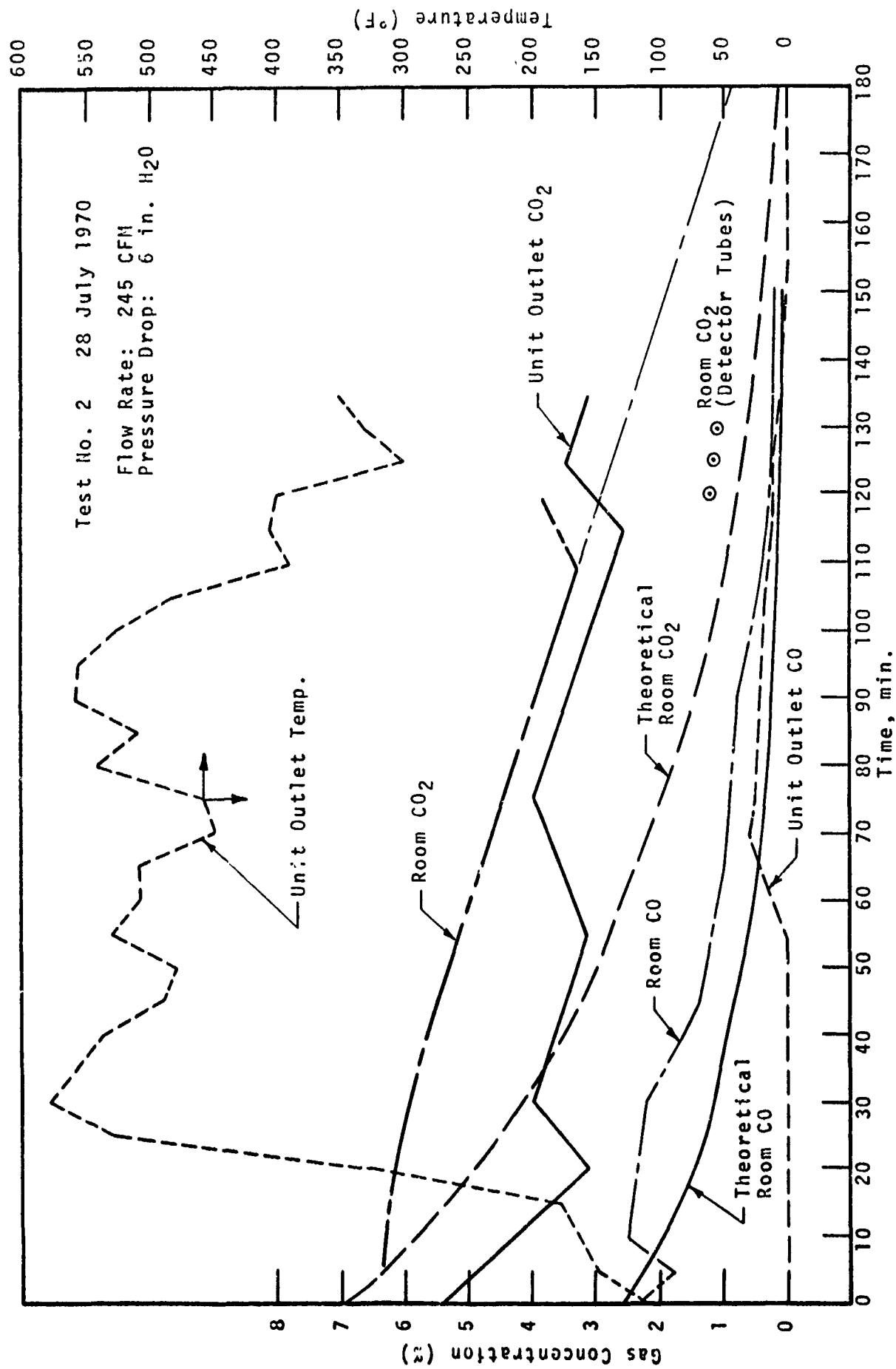


FIGURE 8. PORTABLE SMOKE AND GAS REMOVAL UNIT

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A prototype portable smoke and gas removal unit was developed to clear the atmosphere of a sealed room after a fire. The unit utilizes a series of filters and chemical beds to remove particulate matter, carbon dioxide and carbon monoxide within three (3) hours to such a level that a man may work safely and comfortably. The unit is self-contained, with its own electric motor, blower, filters and chemical beds, all mounted on a portable platform truck with floor lock.			

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Prototype Portable Smoke and Gas Removal Unit Carbon Dioxide Removal Carbon Monoxide Removal Water Vapor Removal Odor Removal Particulate Matter Lithium Hydroxide Hopcalite Silica Gel Activated Charcoal						

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MSAR 71-74

FINAL REPORT

THE DESIGN AND FABRICATION OF ONE (1)
PROTOTYPE PORTABLE SMOKE AND
GAS REMOVAL UNIT (U)

March, 1971

Report No. CR 71.007
Contract No. N62399-69-C-0038 *NEW*

to

Naval Civil Engineering Laboratory
Port Hueneme, California 93043

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An investigation conducted by:
MSA RESEARCH CORPORATION
Division of Mine Safety Appliances Company
Evans City, Pennsylvania 16033

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Each of the following agencies
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TABLE OF CONTENTS

	<u>Page</u>
1.0 INTRODUCTION	1
2.0 DESIGN OF PROTOTYPE UNIT	2
2.1 Lithium Hydroxide Efficiency Tests	2
2.2 System Design	2
2.2.1 Lithium Hydroxide Bed	3
2.2.2 Activated Charcoal Bed	3
2.2.3 Drying Agent	3
2.2.4 Carbon Monoxide Oxidizing Agent	4
2.2.5 Prefilter	4
2.2.6 Particulate Filter	4
2.2.7 Housing	4
2.2.8 Filter and Chemical Bed Construction	4
2.2.9 Blower	4
2.2.10 Motor and Controls	5
2.2.11 Platform Truck	5
2.2.12 Assembly	5
3.0 TEST PROCEDURE	6
4.0 DISCUSSION OF RESULTS	7
5.0 SUMMARY OF TEST RESULTS	8
APPENDIX A: Calculations - Chemical Beds	11
APPENDIX B: Mass Balance Calculations for Test No. 2	12

LIST OF TABLES

- I. Bed Replenishment List
- II. Test Apparatus
- III. Test Data, Test No. 2
- IV. Filter and Bed Element Changes

LIST OF FIGURES

- 1. Lithium Hydroxide Efficiency Test No. 1
- 2. Lithium Hydroxide Efficiency Test No. 2
- 3. Portable Smoke and Gas Removal Unit
- 4. Assembly Drawing, Portable Smoke and Gas Removal Unit
- 5. Temporary Environmental Test Facility
- 6. Access Port Structure
- 7. Interior of Temporary Environmental Test Facility
- 8. Data Curves, Test No. 2

SUMMARY

A prototype portable smoke and gas removal unit was developed to clear the atmosphere of a sealed room after a fire.

The unit utilizes a series of filters and chemical beds to remove particulate matter, carbon dioxide and carbon monoxide within three hours to such a level that a man may work safely and comfortably.

The unit is self-contained, with its own electric motor, blower, filters and chemical beds, all mounted on a portable platform truck with floor lock.

FINAL REPORT

Contract No. N62399-69-C-0038

Naval Civil Engineering Laboratory
Port Hueneme, California 93043

THE DESIGN AND FABRICATION OF ONE(1) PROTOTYPE PORTABLE SMOKE AND GAS REMOVAL UNIT (U)

1.0 INTRODUCTION

The portable smoke and gas removal system is required for the purpose of removing particulate matter, carbon dioxide, carbon monoxide and other toxic gases from the atmosphere of a sealed room. The sealed room is to be 7,500 cu ft, filled with smoke and gases from Class A or Class C fires. It is required that the unit reduce the air contaminants to such a level as to permit habitation within a few hours, assuming the oxygen content of the air is at a normal level. The temperature of the air in the room is assumed to range from 50°F to 90°F while the unit is in operation.

It is required that the unit be self-contained with an integral motor, blower, and filters. The unit must be easily portable and must pass readily through standard 33 in. and 36 in. wide doorways.

A preliminary study indicated that the unit should contain a prefilter, a particulate filter, a charcoal filter to remove toxic gases, a drying agent to remove water vapor, a carbon monoxide oxidizer and a carbon dioxide absorbing agent.

The unit must be capable of performing with carbon dioxide concentrations as high as 10%, caused by the fire and possible use of carbon dioxide extinguishers.

2.0 DESIGN OF THE PROTOTYPE UNIT

Since there was no published information as to the efficiency of lithium hydroxide (LiOH) in absorbing carbon dioxide (CO₂) when the CO₂ concentration approached the 10% level, it was felt necessary to conduct laboratory tests to establish the weight of LiOH required to absorb 1 lb of CO₂ at a CO₂ concentration of about 10%.

2.1 Lithium Hydroxide Efficiency Test

Two tests were conducted at 10% CO₂ concentration at the beginning of each test to determine the efficiency of LiOH as an absorption agent for CO₂. In each test, a canister, 8-3/8 inch ID x 12 inch long was filled with 9 lb of LiOH and placed inside a room of about 600 cu ft capacity. Air from the room was moved through the canister at the rate of 20 cu ft per minute (CFM). The values of temperature of the gases from the canister and the concentration of CO₂ in the room and at the outlet of the canister were measured every few minutes. These values for the two tests are shown as a function of time in Figures 1 and 2.

To establish initial concentration of CO₂ in the room, the room was charged with a predetermined volume of CO₂ by releasing balloons filled with CO₂ inside the room, and the CO₂ concentration measured by an Orsat apparatus. An MSA model 300 Lira instrument was used to measure the CO₂ concentration exiting from the canister. As may be noted from Figure 2, a peak canister outlet temperature of about 270°F occurred at approximately 10 minutes after the start of test.

At the end of tests, the spent LiOH was titrated with acid to determine the volume of CO₂ absorbed by LiOH bed. For the two tests, the volume of CO₂ absorbed was found to be 49 and 49.6 cu ft, respectively. It was then assumed that the small residual CO₂ in the room would have been absorbed by LiOH were the test continued further than the 3 hour duration of the tests reported here. Making a small adjustment for this residual gas, it was estimated that 9 lb of LiOH in the canister was capable of absorbing 6 lb of CO₂. This ratio was used in determining the quantity of LiOH to be used in the Smoke and Gas Removal Unit.

2.2 System Design

The Smoke and Gas Removal Unit was to be designed to absorb smoke and gases generated in a 7500 cu ft room during a Class A or Class C fire and to reduce the concentrations of

the various gases to levels safe for normal habitation without regard to oxygen concentrations. Other design requirements are given in contract specification, N62399-69-C-0038.

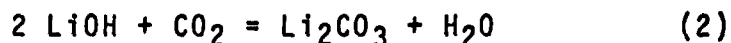
2.2.1 Lithium Hydroxide Bed. It was assumed that a room of 7500 cu ft capacity will have approximately 14 lb of carbon monoxide (CO) after a class A or class C fire. Hopcalite, a proprietary catalytic agent of coprecipitated manganese and copper oxides, was decided upon to oxidize this CO into CO₂ which was then to be absorbed by the LiOH bed. Based upon the reaction shown in Equation (1), it was determined that 14 lb of CO will produce 22 lb of CO₂.



In addition, a 10% concentration of CO₂ in the room at the end of fire was calculated to be equivalent to approximately 65 lb of CO₂. Therefore, a total of 87 lb (65 + 22) of CO₂ was to be absorbed by the LiOH bed. At the absorption rate of 0.67 lb of CO₂ per lb of LiOH, a total of 130.5 lb of LiOH was considered necessary for the purposed prototype unit.

2.2.2 Activated Charcoal Bed. The contract specification required a minimum of twenty lb of activated charcoal to remove 4 lb of toxic gases. The system was designed to provide 25 lb of activated charcoal, 6-10 mesh, MSA Part No. 21104. This quantity was based on a 0.25 second contact time for the gas flowing through the bed. The calculations are shown in Appendix A.

2.2.3 Drying Bed. A drying bed was considered necessary for the removal of water from the air to prevent poisoning the hopcalite, the CO oxidizing agent. It was decided to use silica gel to remove most of the water generated during the carbon dioxide-lithium hydroxide reaction. From the chemical reaction shown in Equation (2), it was estimated that a total of 35.6 lb of water will be generated in the LiOH trays.



Approximately 140 lb of silica gel is required to absorb 35.6 lb of water. However, due to limitations in the weight, size, and pressure drop through the unit, it was considered impractical to aim for complete removal of water generated during CO₂ absorption. It was, therefore, decided to limit the quantity of silica gel to 45 lb.

2.2.4 Carbon Monoxide Oxidizing Agent. The material for oxidizing carbon monoxide was hopcalite. A total of 55 lb moisture tolerant hopcalite was used (MSA Part No. 21215). This quantity was based on a 1/4 second contact time. Calculations to determine the required amount are shown in Appendix A. Moisture tolerant hopcalite has a higher capacity to convert CO to CO₂ than do the standard hopcalite materials. It will pass less than 0.01% CO out with 0.1% CO in with moisture level of 45 mg H₂O per gram hopcalite. The temperature limit on the hopcalite is 800°F.

2.2.5 Prefilter. The MSA AIR-O-KAY prefilter No. 15-38191, with modifications, was selected as the prefilter. The AIR-O-KAY prefilter is useful to extend the life of the more costly DUSTFOE elements by stopping and holding a high percentage of the larger particulate matter. Initial pressure drop at 1000 SCFM is less than 0.1 in. W.G.

2.2.6 Particulate Filter. The MSA DUSTFOE filter No. 15-87407, with modifications, was selected as the particulate filter. This filter, which corresponds to the MSA B-1000, provides 55% maximum penetration and 0.25 in. W.G. maximum initial pressure drop when penetration tested with 0.3 micron diameter DOP smoke particles in accordance with MIL-STD-282.

2.2.7 Housing. As shown in Figure 3, the system was designed with a stainless steel housing with a removable cover. The housing is 28 in. ID x 48 in. high and is equipped with two support flanges, one for the two-filter assembly and one for the chemical bed.

2.2.8 Filter and Chemical Bed Construction. Figure 3 shows the beds arranged in their stacked sequence. Air flow is vertically upward through the filters and chemical beds, with the inlet in a plenum chamber below No. 1, Prefilter. The two filters are riveted together into one assembly.

Each filter and bed is constructed of a rolled stainless steel flange with a grid support of heavy duty stainless steel wire cloth. Fine mesh screens and fiberglass cloths are used in each chemical bed to retain the bed particles.

2.2.9 Blower. The blower selected is a high-pressure direct-driven centrifugal blower, Dayton Electric Manufacturing Company, No. 4C108. When driven with a 1 HP motor, delivery rates are as follows:

Static Pressure, in. H ₂ O	1	2	3	4	5	6
CFM at 3450 RPM	810	748	682	610	510	370
CFM at 2700 RPM	634	585	534	477	398	289

2.2.10 Motor and Controls. The motor selected is a 1 HP permanent magnet motor, 3600 RPM, Applied Motors Inc., No. VC3632-497-56B. The motor is equipped with vibration isolator mounts and a special housing and stand fabricated by MSAR.

An SCR power supply, speed control and switch is panel mounted in the housing. A 75 ft power cord of 3-conductor No. 12 wire and a cord holder are provided with the unit.

2.2.11 Platform Truck. A 30 in. wide x 60 in. long aluminum platform truck is provided to support the system. The truck is equipped with a foot-operated floor lock and a handle bar.

2.2.12 Assembly. In Figure 4 is an assembly drawing of the system, ref. MSAR drawing A-SK-1818-2.

3.0 TEST PROCEDURE

Test No. 1

Upon completion of fabrication the portable smoke and gas removal unit was loaded and assembled in preparation for testing. The chemical beds and filters were loaded with chemicals in the order and amounts shown in Table I. The test apparatus listed in Table II was assembled and prepared for testing.

The MSAR fire testing facility was selected for the test building. Since it is a 10,000 cu ft building, the excess volume of 2,500 cu ft was reduced to the required 7,500 cu ft by inflating a 2,500 cu ft vinyl bag of air inside the facility. Obvious leaks in the building were sealed by taping.

Before the test, a considerable amount of smoke was generated in the test building by burning a rubber tire and styrofoam material, and CO and CO₂ gases were added from plastic bags. The circulating fan was used to mix the gases in the room and the test was started.

After only 20 minutes, the test was stopped because of the observed leakage of gases from the building. It was evident that the building was not sealed properly for the test because of the excessive leakage of smoke from the corrugated metal seams and joints. The rate at which the CO and CO₂ concentrations in the room dropped during this time was also judged to be abnormally high compared to the lithium hydroxide efficiency tests run previously. Therefore, the test was discontinued.

Corrective action on the test building was considered but sealing of the building was found to be impractical because the sealing materials were not compatible with other fire testing work. The usage of other available MSAR buildings, and also other industrial buildings in the area, was evaluated and ruled out for economic, insurance or liability considerations. At this point it was decided to prepare plans for a temporary environmental test facility employing two inflatable vinyl bags, each having a capacity of 3,750 cu ft. Vinyl bags were chosen as the environmental test facility since these and Mylar bags are used for gas sampling. Although we have no permeability data on diffusion of CO and CO₂ through the vinyl bags, we believed it minimal since the test was conducted within a half hour after releasing the CO and CO₂ into the environmental test facility. This test is described below.

Test No. 2

A test facility composed of two(2) 3,750 cu ft vinyl bags with a sealed access port was designed, fabricated and assembled. The bags were individually attached and sealed to the access port frame. The facility is illustrated in the following figures:

Figure 5 - Temporary Environmental Test Facility

Figure 6 - Access Port Structure

Figure 7 - Interior of Temporary Environmental Test Facility

Figure 5 shows the exterior of the temporary environmental test facility. The necessary testing volume is formed by two(2) 3,750 cu ft vinyl bags, each approximately 15 ft dia. x 20 ft long. Bags of this type, in smaller sizes, had been successfully used at MSAR for similar applications.

Figure 6 shows the access port structure which performs the following functions:

- Provides a sealed access door for passage of personnel and the portable smoke and gas removal unit.
- Provides a support platform for the portable smoke and gas removal unit.
- Joins and anchors the vinyl bags in the middle of the facility.

A view of the interior of one of the bags, after inflation, is shown in Figure 7.

A 900 CFM circulating blower was set up inside the facility to insure mixing of the atmosphere especially the CO and CO₂ gases when released into the facility.

Once the facility and measuring equipment were connected, a container of styrofoam was burned to produce smoke in the building. Predetermined amounts of the CO and CO₂ were then released inside the facility by opening previously filled vinyl bags. The quantities measured and the equipment used were the same as described in Test No. 1, and detailed in Table II. The data recorded during the test are given in Table III and plotted in Figure 8.

4.0 DISCUSSION OF RESULTS

Test No. 2. After 110 minutes, the CO₂ LIRA instrument began to behave erratically, as noted by increase in the facility CO₂ level. This may have been caused by condensation of water vapor within the instrument. The LIRA instrument was immediately checked by measuring the CO₂ with 3% CO₂-in-air calibrating gas. The LIRA gave a 4% CO₂ level, indicating that the LIRA was reading high. Another check was made with the LIRA in which air was sampled. The LIRA gave a reading of 0.5%. Since air is essentially 0% CO₂, the LIRA was reading high by 0.5 to 1.0%.

A chemical assay of spent chemicals and a study of the filter elements was made after the test. The results are itemized in Table IV. A 1 lb sample of LiOH was removed from each bed and acid titrated to measure absorbed CO₂.

A total of 631 ft³ CO₂ was calculated from this analysis; the initial or inlet bed absorbed 252 ft³, the middle bed 224 ft³ and the outlet bed 155 ft³. A mass balance calculation was made and this is given in Appendix B. From a mass balance approach, a 1% CO₂ concentration was present in the test facility.

The adsorption of water by the silica gel was determined by weight. The 45 lb charge of silica gel weighed 55-3/4 lb, or a net gain of approximately 24%.

The theoretical (maximum) removal rates of CO₂ and CO for the test are plotted on Figure 8. The figure shows that time to reach 1% CO₂ requires 110 minutes at the 200 CFM flow rate. The actual performance lagged behind the calculated maximum removal rate. This is also shown to be the case with CO; the actual performance rate lags the calculated rate.

The absorption rates were computed from a rate equation assuming that CO₂ concentration is 0% leaving the LiOH beds (100% removal efficiency). The bed configuration of the unit has the hopcalite bed on the outlet end. Therefore, CO₂ converted from CO was expelled back into the test facility. As a result the rate equations representing this configuration for CO₂ and CO concentrations in the chamber are respectively

$$X = X_0 e^{-\frac{Qt}{V}} + \frac{Q}{V} Y_0 t e^{-\frac{Qt}{V}} \quad (3)$$

(CO₂ conc = removal + generation) for CO₂

and $Y = Y_0 e^{-\frac{Qt}{V}}$ for CO

(CO conc = removal + no generation)

where X = Instantaneous volume of CO₂ in the test facility, ft³.

X₀ = initial CO₂ volume, 525 ft³

Y₀ = Instantaneous volume of CO in the test facility, ft³.

Y₀ = initial CO volume, 195 ft³

V = chamber volume, ft³ (7500 ft³)

Q = flow rate, cfm (200 cfm)

t = time, minutes

These equations were put into a computer and the computer readouts for CO₂ and CO concentrations are plotted in Figure 8, as mentioned previously.

With a bed arrangement in which a LiOH bed follows the hopcalite bed, CO₂ theoretically would not be expelled into the test facility. The second term in Equation (3) will therefore be equal to zero, giving

$$X = X_0 e^{-\frac{Qt}{V}} \quad (4)$$

Theoretically, therefore, the removal of CO₂ would be more rapid whereas the concentration of CO would be unaffected. In this latter case, 1% CO₂ concentration would be achieved in 75 minutes.

With the configuration tested, with 100% removal of CO₂ through the LiOH and 1.0% CO₂ in two hours in the test facility, the flow rates required for various initial CO₂ concentrations are as follows:

Initial CO ₂ Conc (%)	Flow Rates (CFM)
8	358
7	327
5	201

5.0 SUMMARY OF TEST RESULTS

In summary, the test program has demonstrated the following:

1. The unit effectively removes CO
2. The unit removes CO₂
3. The unit removes some water, but not all the water produced
4. Further testing is required to demonstrate the performance of the unit.

APPENDIX A

CALCULATIONS: CHEMICAL BEDS

The system design is based on bed diameters of 27 inches. It was assumed that a 1/4 second contact time in the charcoal and Hopcalite beds should be adequate.

Activated Charcoal Beds

For a flowrate (Q) through the charcoal bed of cross-sectional area (A), the thickness (S) of the bed to insure a contact time (t) is given by:

$$S = \frac{Qt}{A}$$

For a flowrate of 200 CFM through a cross-sectional area of 4.0 sq ft and a contact time of 1/4 second (1/240 minute), the bed thickness is given by:

$$S = \frac{200 \times 1}{240 \times 4} = \underline{0.21 \text{ ft}}$$

The total weight of activated charcoal needed in the unit is, therefore,

$$\begin{aligned} W &= \text{density of charcoal} \times \text{volume of the bed} \\ &= 30 \times 4.0 \times 0.21 \\ &= \underline{25.2 \text{ lbs}} \end{aligned}$$

Hopcalite Bed

Since it is planned to use the same size beds for both charcoal and Hopcalite, the weight of Hopcalite required is given by:

$$\begin{aligned} W &= \text{density of Hopcalite} \times \text{volume of the bed} \\ &= 65 \times 4.0 \times 0.21 \\ &= 54.5 \text{ lbs, say } \underline{55 \text{ lbs}} \end{aligned}$$

APPENDIX B

MASS BALANCE CALCULATIONS FOR TEST NO. 2

Chemical Assay of Beds, LiOH

Inlet Bed	252 ft ³ CO ₂
Middle Bed	224 ft ³ CO ₂
Outlet Bed	154.7 ft ³ CO ₂
Total	630.7 ft ³ CO ₂

Mass Balance on System

Initial CO ₂ Conc.	7%
Initial CO Conc.	2.6%

Initial Quantity CO₂ in the test facility

$$7500 \text{ ft}^3 \times 0.07 = 525.0 \text{ ft}^3 \text{ CO}_2$$

Initial Quantity CO in the test facility

$$7500 \text{ ft}^3 \times 0.026 = 195 \text{ ft}^3 \text{ CO}$$

CO Balance

Volume of CO at the beginning of the test = 195 ft³

Concentration of CO at the end of the test = 0.2%

Volume of CO at the end of test = $7500 \times 0.002 = 15 \text{ ft}^3$

CO converted to CO₂ during the test = $195 - 15 = 180 \text{ ft}^3$

Total volume of CO₂ available for absorption = Initial
CO₂ in the test facility
plus CO₂ converted from CO
= $525 + 180 = 705 \text{ ft}^3$

TABLE I
BED REPLENISHMENT LIST

PORTABLE SMOKE AND GAS REMOVAL UNIT
PROTOTYPE UNIT

<u>Bed No.</u>	<u>Amount Required</u>	<u>Description</u>
1	1	Prefilter Assembly, MSAR SK 1-227-1
2	1	Filter Assembly, MSAR SK 1-231-1
3	25 lb	Activated charcoal, 6-10 mesh MSA part No. 21104
4	45 lb	Silica Gel, 8-14 mesh MSA part No. 21177
5 } 6 } 7 }	45 lb in each bed	Lithium hydroxide, 4-8 mesh MSA part No. 20457
8	55 lb	Hopcalite, 8-12 mesh. MSA part No. 21215

TABLE II
TEST APPARATUS

<u>Item</u>	<u>Characteristic</u>	<u>Apparatus Used</u>	<u>Location</u>
1	CO ₂ Concentration	MSA Model 300 LIRA Analyzer, with sample pump.	IN - Environmental chamber OUT- Discharge gas stream of unit
2	CO Concentration	MSA Explosimeter with special calibration, with sample pump.	IN - Environmental chamber OUT- Discharge gas stream of unit
3	O ₂ Concentration	Beckman Model C2 Oxygen Analyzer	IN - Environmental chamber
4	Pressure Drop	Water Draft Gauge	IN - Unit prefilter plenum OUT- Environmental chamber
5	Temperature	API Temperature Indicator, Iron-constantan Thermocouples	IN - Environmental chamber OUT- Discharge gas stream of unit SHELL-On O.D. of unit MOTOR-On unit blower motor case
6	Gas Flow	Taylor No. J012 Aenometer	Discharge gas stream of unit
7	CO ₂ Concentration	MSA Detector Tube, Part No. 85976	Use manual sample pump to withdraw gas sample from the desired location. Color staining indicates concentration
8	CO Concentration	MSA Detector Tube, Part No. 91229	

TABLE III
TEST DATA, TEST NO. 2
Portable Smoke and Gas Removal Unit

Date: 29 July 1970

Date: 29 July 1970

Time, min.	CO ₂ Conc.		CO Conc.		O ₂ %	ΔP In H ₂ O	Temp. °F			
	IN	OUT	IN	OUT			IN	OUT	SHELL	MOTOR
1730	Started fire, burning container of styrofoam to fill space with smoke.									
	Started releasing CO ₂ and CO gases into bags.									
	Amount released:									
	CO - 230 SCF, (3.42% Concentration)									
	CO ₂ - 540 SCF, (7.98% Concentration)									
	Started circulating blowers.					Started test.				
1815	5.5	---	2.4	---	18	6.25	80	110	80	90
1820	7.0	---	1.8	---	18	6.25	70	150	80	90
1825	6.4	---	---	---	18	6.25	75	150	80	90
1830	6.3	---	2.5	---	18	6.25	70	170	70	85
1835	---	3.6	---	0	18	6.25	70	180	70	85
1840	---	3.2	---	0	18	6.25	70	320	70	85
1845	6.1	---	---	0	18	6.25	75	530	60	90
1850	---	4.0	2.25	---	18	6.25	85	580	60	100
1855	---	3.8	---	0	18	6.25	80	560	60	100
1900	5.6	---	1.62	---	18	6.25	80	540	65	100
1905	5.6	---	1.4	---	18	6.25	80	490	70	100
1910	---	---	---	---	18	6.25	80	485	70	105
1915	---	3.2	---	0	18	6.25	80	530	80	110
1920	4.8	---	1.2	---	18	6.25	80	510	80	110
1925	4.7	---	1.0	---	18	6.25	80	510	80	110
1930	---	3.7	---	0.62	18	6.25	80	450	80	110
1935	---	4.0	---	0.5	18	6.25	80	460	85	115
1940	4.4	---	0.87	---	18	6.25	80	540	85	115
1945	---	3.7	---	0.87	18	6.25	85	510	85	115
1950	4.0	---	0.87	---	18	6.25	85	560	80	115
1955	---	3.2	---	0.45	18	6.25	80	560	80	110
2000	3.7	---	0.54	---	18	6.25	80	525	80	110
2005	---	2.9	---	0.35	18	6.25	80	485	80	110
2010	3.4	---	0.4	---	18	6.25	75	390	80	110
2015	---	2.6	---	0.25	18	6.25	75	405	80	110
2020	3.8	---	0.32	---	18	6.25	80	400	80	110
2025	---	3.5	---	0.25	18	6.25	75	300	80	110
2030	---	---	---	---	18	6.25	--	330	--	---
2035	---	3.2	---	---	18	6.25	75	350	75	105

TABLE III (continued)

Time, min.	CO ₂ Conc.		CO Conc.		O ₂ %	ΔP In. H ₂ O	Temp. °F			
	IN	OUT	IN	OUT			IN	OUT	SHELL	MOTOR
2050	---	2.8	---	0	18	6.25		350		
2055	3.0	---	0.2	---						
<p>Checked calibration of CO₂ LIRA instrument with 3% CO₂ calibration gas. Result: 4.1 reading. Therefore, CO₂ LIRA readings taken during the latter stages of the test are questionable although the instrument had been calibrated and checked prior to the test. This difficulty could possibly have been caused by the condensation of water vapor in the sample lines during the latter stages</p>										
2055	Room CO ₂ :	1.2% Conc. measured with a CO ₂ detector tube.								
	Room CO:	120 ppm, measured with a CO detector tube.								

TABLE IV
FILTER AND BED ELEMENT CHANGES
Portable Soot and Gas Removal Unit

Test 2

No.	Element	Weight, lb		Remarks
		Before Test	After Test	
1	Prefilter, MSA Air-0-Kay	--	--	Collected numerous black particles
2	Particulate Filter, MSA Dustfoe	--	--	Collected some black particles, including some activated charcoal from bed above
3	Activated charcoal, 6-10 mesh, MSA part No. 21104	25	29	+ 4
4	Silica gel, 8-14 mesh, MSA part No. 21177	45	55-3/4	+10-3/4 10.75 lb H ₂ O absorbed
5	Lithium hydroxide, 4-8 mesh, MSA part No. 20457	45	64	+19 252 ft ³ CO ₂ absorbed
6	Lithium hydroxide, 4-8 mesh, MSA part No. 20457	45	61-3/4	+16-3/4 224 ft ³ CO ₂ absorbed
7	Lithium hydroxide, 4-8 mesh, MSA part No. 20457	45	54-3/4	+ 9-3/4 155 ft ³ CO ₂ absorbed
8	Hopcalite, 8-12 mesh, MSA part No. 21215	55	54-3/8	- 5/8 -----

11

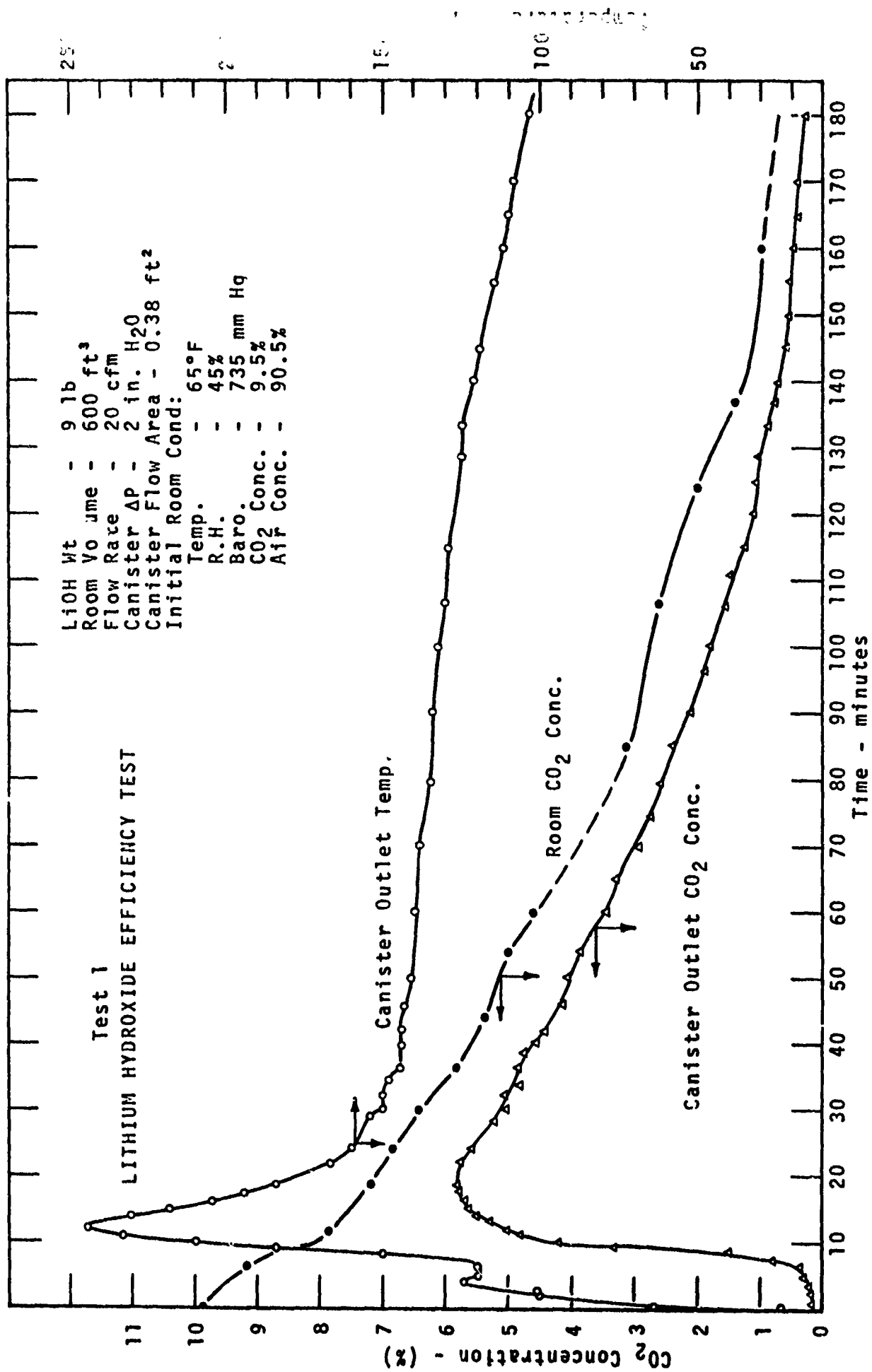


FIGURE 1

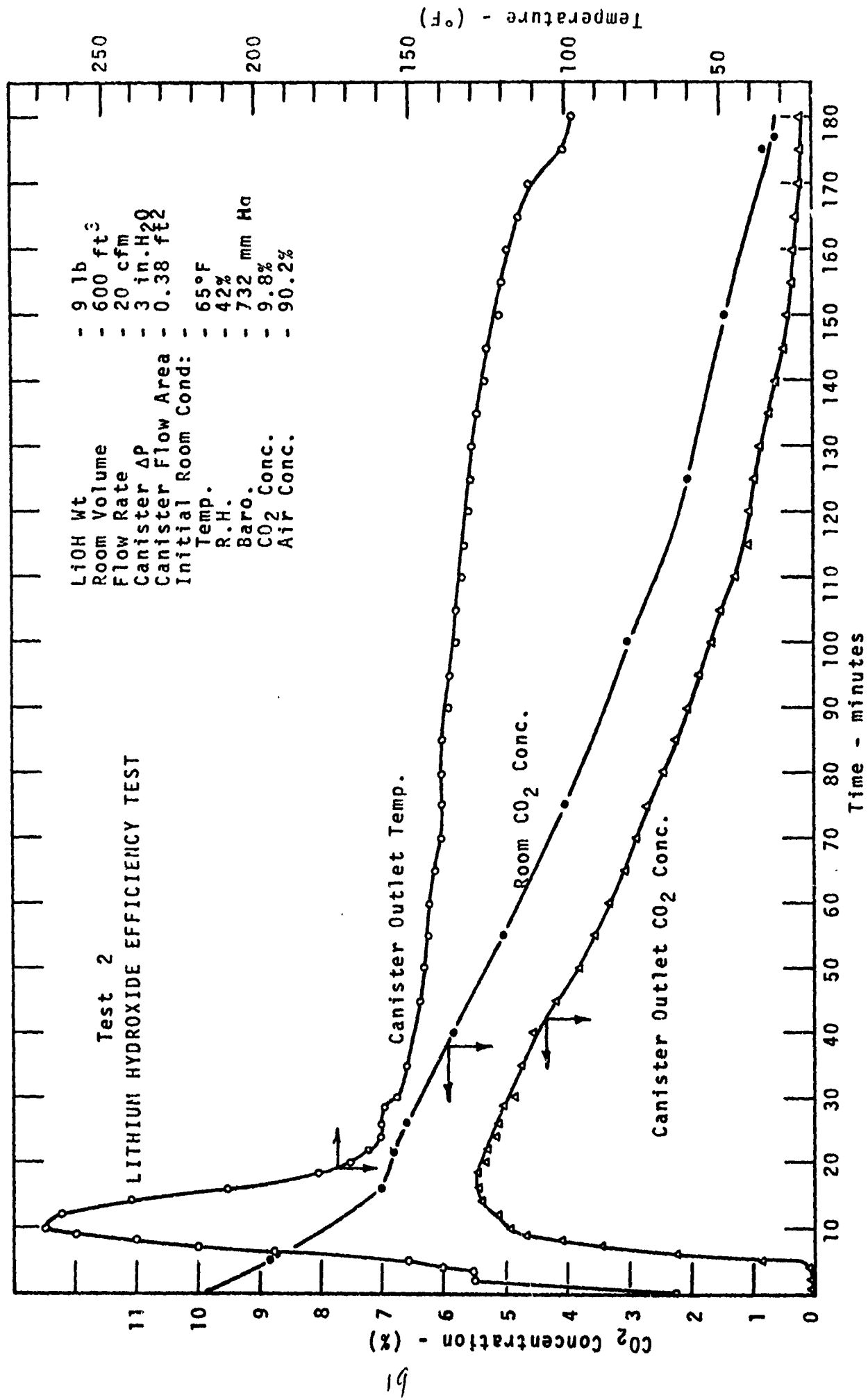


FIGURE 2

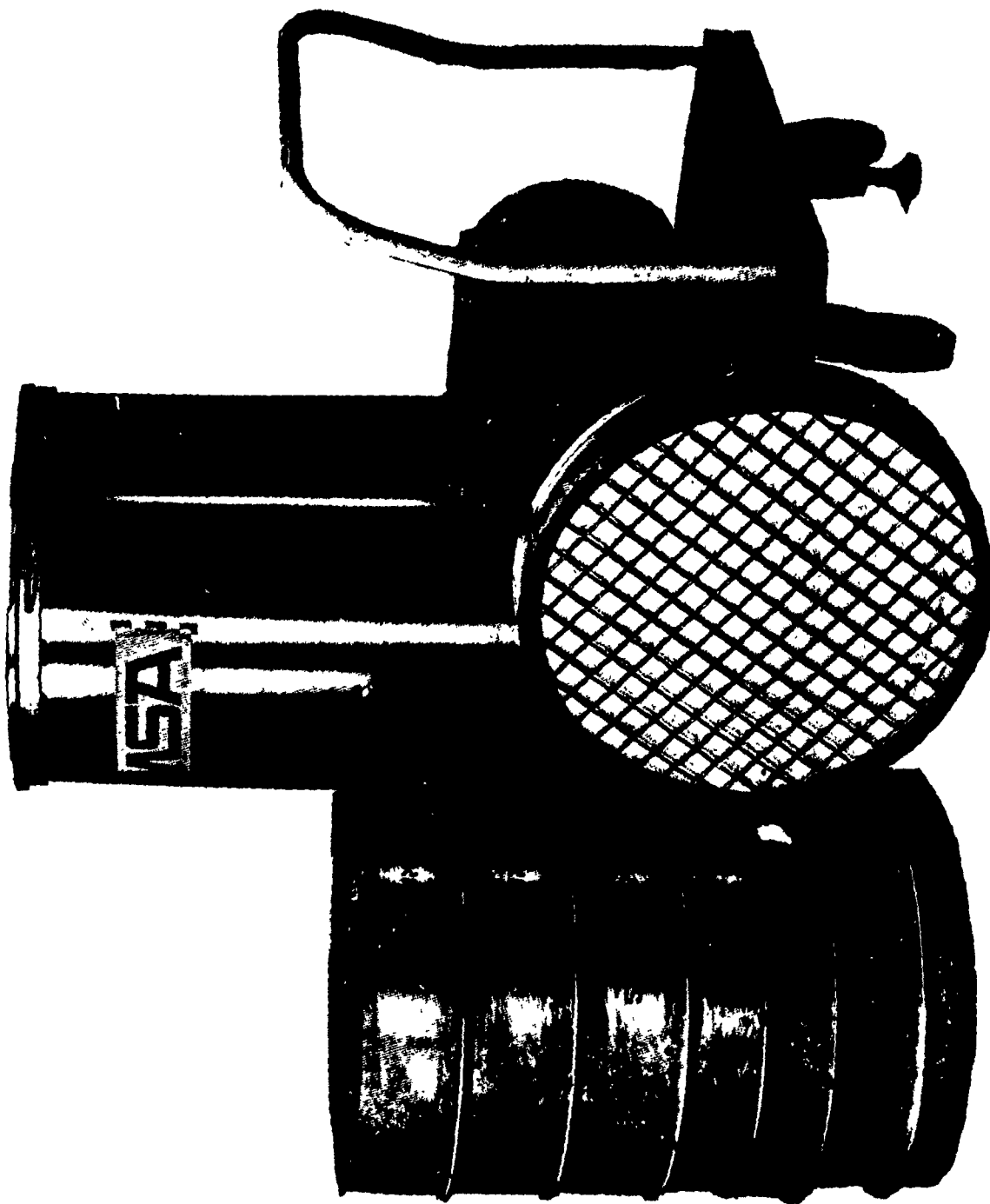


FIGURE 3. PORTABLE SMOKE AND GAS REMOVAL UNIT

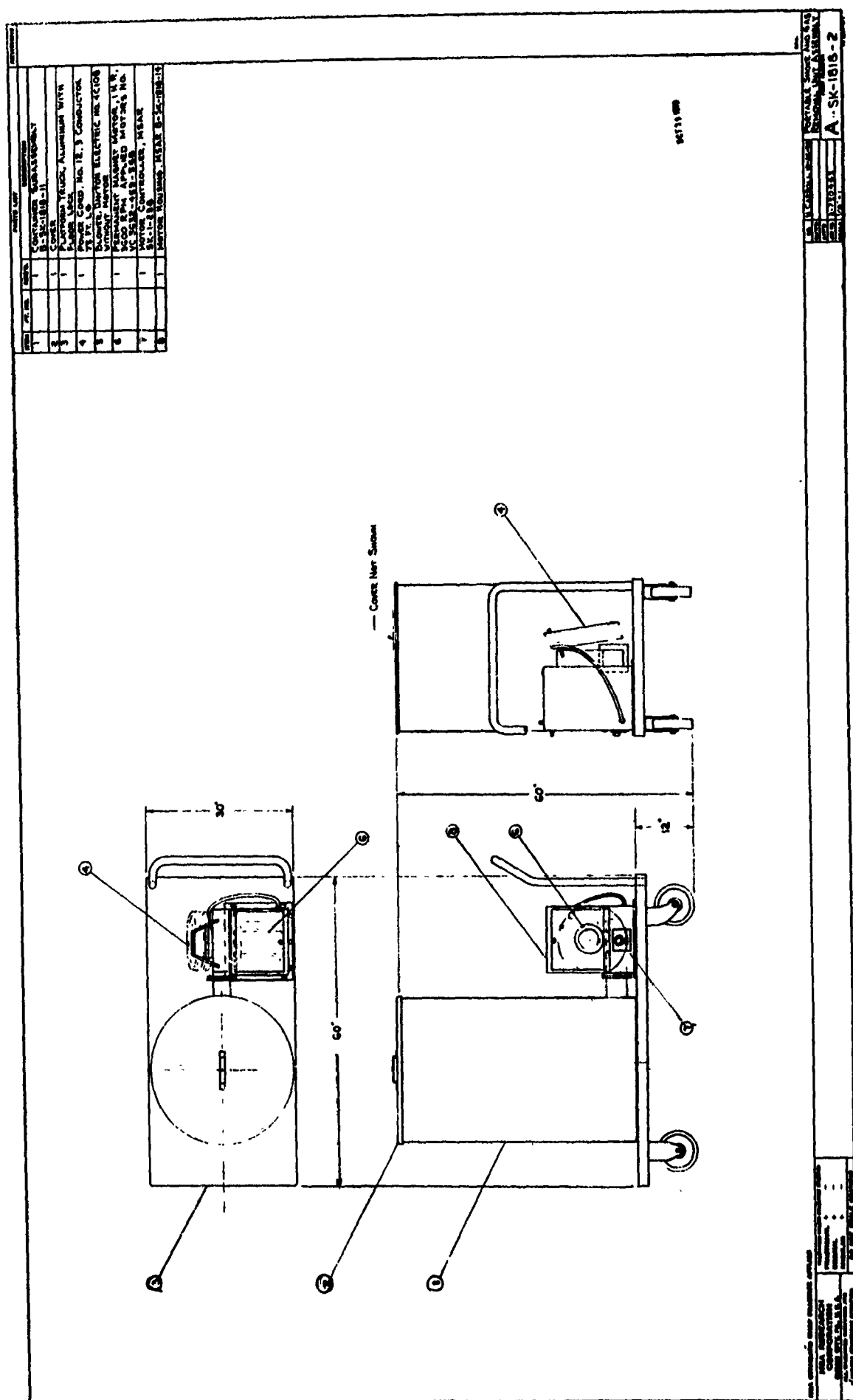




FIGURE 5. TEMPORARY ENVIRONMENTAL TEST FACILITY

NOT REPRODUCIBLE

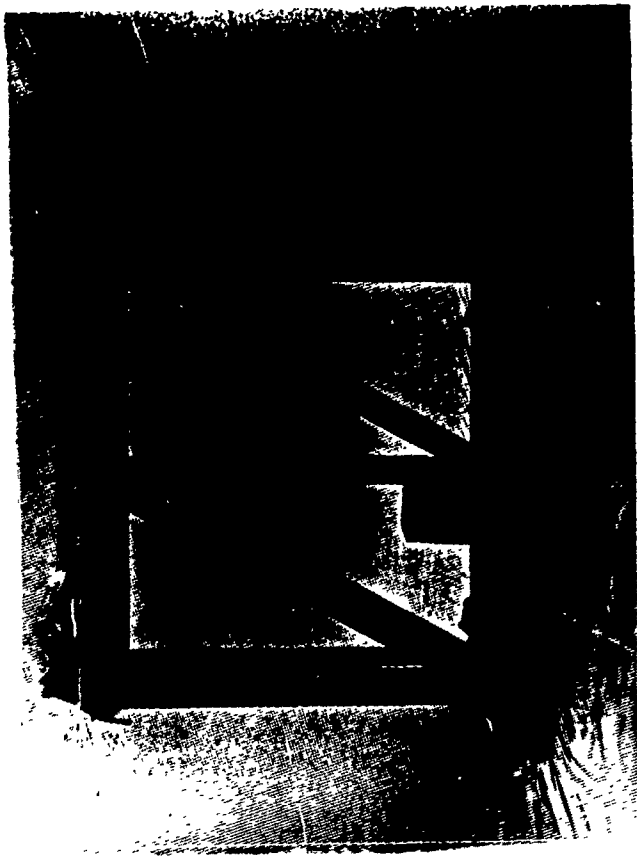


FIGURE 6. ACCESS PORT STRUCTURE



FIGURE 7. INTERIOR OF TEMPORARY ENVIRONMENTAL TEST FACILITY

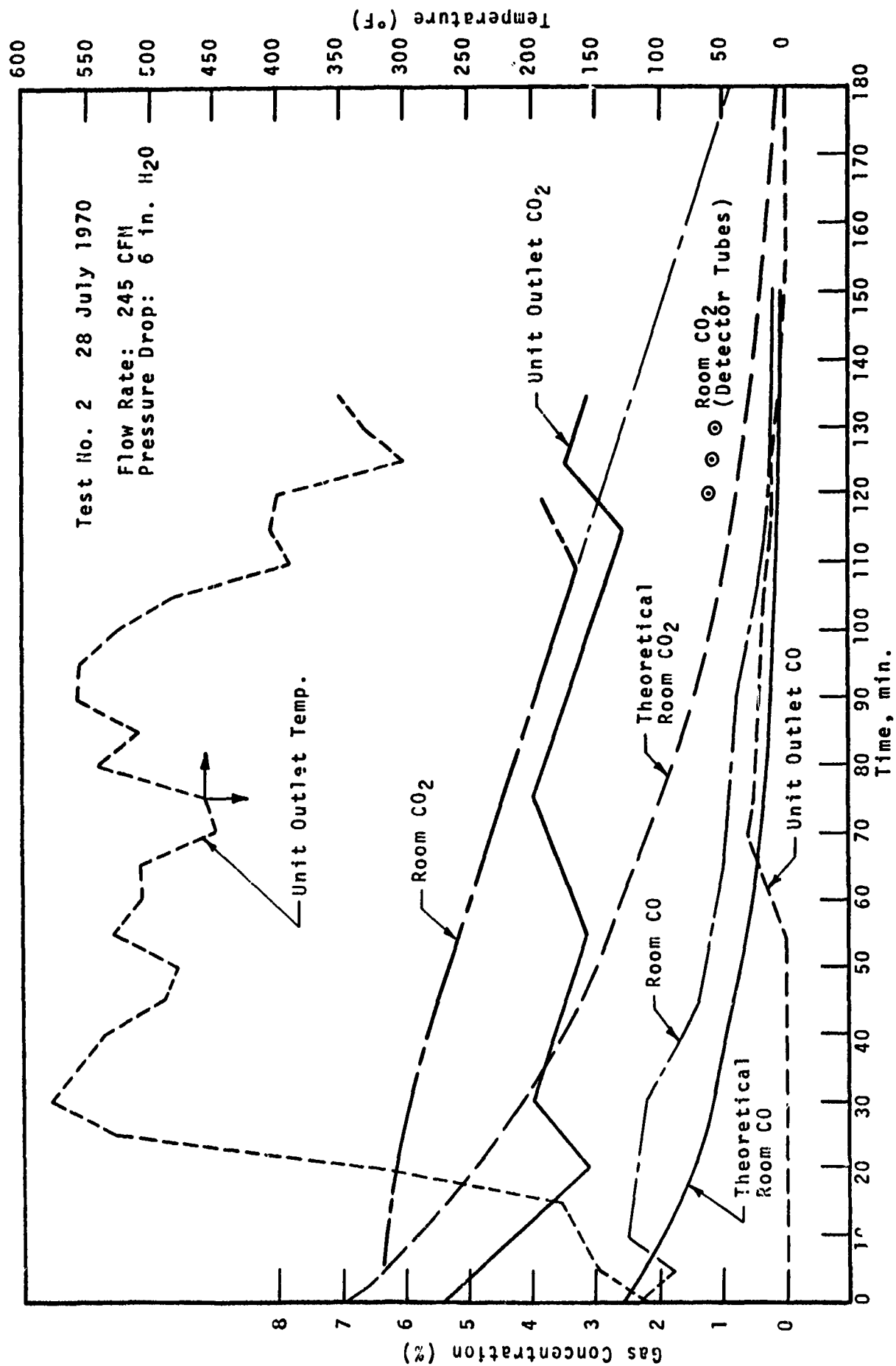


FIGURE 8. PORTABLE SMOKE AND GAS REMOVAL UNIT

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13. ABSTRACT		
<p>A prototype portable smoke and gas removal unit was developed to clear the atmosphere of a sealed room after a fire.</p> <p>The unit utilizes a series of filters and chemical beds to remove particulate matter, carbon dioxide and carbon monoxide within three (3) hours to such a level that a man may work safely and comfortably.</p> <p>The unit is self-contained, with its own electric motor, blower, filters and chemical beds, all mounted on a portable platform truck with floor lock.</p>		

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Prototype Portable Smoke and Gas Removal Unit Carbon Dioxide Removal Carbon Monoxide Removal Water Vapor Removal Odor Removal Particulate Matter Lithium Hydroxide Hopcalite Silica Gel Activated Charcoal						

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(PAGE 2)

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